

OPHTHALMOLOGIC APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to an
ophthalmologic apparatus.

Related Background Art

 In the ophthalmologic medical field, fluorescent
contrast photography or image pickup is widely
10 conducted in which a fluorescent contrast medium is
injected through a vein of a subject into an anterior
or retinas and choroids. The fluorescent contrast
medium injected into the vein of the subject reaches
a subject eye via blood circulation. At first, the
15 fluorescent contrast medium is gradually concentrated
in the subject eye as time passes. After reaching a
maximum level, the concentration of the fluorescent
medium in the subject eye gradually decreases due to
absorption and excretion by circulation in the body.
20 That is, in fluorescent contrast photography, in
principle, a photograph site becomes rapidly bright
from a dark state, and then gradually darkens, as
time passes after injection of the fluorescent medium.

 In fluorescent contrast photography, the
25 variations in brightness described above are
important information for understanding the states of
circulation of the body fluid in the eye and the body.

Accordingly, the illuminating light intensity and the exposure conditions and sensitivity of photographing means are not usually changed at the time of fluorescent contrast photography.

5 A silver halid film is mainly used as photographing means, but in recent years, electronic image photography using a CCD or the like has been performed (Japanese Patent Application Laid-Open No. H10-260487).

10 In the example of the conventional technique described above, however, the brightness of the subject changes rapidly with time. Photography using a conventional silver halid film has a wide latitude (exposure allowable range), thus making it possible
15 to photograph an image having no problems in practice with respect to a change in brightness when the subject is being photographed.

 However, electronic image pickup means has a latitude smaller than that of the silver halid film,
20 so that the photographed image may be too dark with respect to a change in brightness of the subject, or the brightness may be saturated. Thus, for obtaining an appropriate image, a gain (signal amplification factor) or the illuminating light intensity must be
25 changed but consequently, important information, i.e., a change in brightness of the subject described above, is lost, and the image thus obtained is very

difficult to use for diagnosis for circulation.

SUMMARY OF THE INVENTION

5 The object of the present invention is to solve the problems described above and to provide an ophthalmologic apparatus capable of obtaining an image with proper exposure.

10 The ophthalmologic apparatus according to the present invention for achieving the above object corrects an image group consisting of a plurality of images photographed while changing photographic conditions, using each of the photographic conditions of images in the image group, so that the image in the image group is expressed as an image photographed under predetermined photographic conditions.

15 Furthermore, the photographic conditions include at least one type of information of an amplification factor of image pickup means, the illuminating light intensity for a subject eye, and the intensity of transmitted photographing light of means for adjusting the intensity of photographing light reaching the image pickup means.

20 Further objects and configurations of the present invention will be apparent in embodiments described later.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an apparatus;
FIG. 2 is an explanatory view of control means;
FIG. 3 is an outline view of the apparatus;
FIG. 4 is an explanatory view of a group of

5. input means;

FIG. 5 is a block circuitry diagram of image
process storing means;

FIG. 6 is a flowchart diagram of processing;

FIG. 7 shows an example of display of images in
10 an image group S_0 ;

FIG. 8 is a lookup table of an image P_n ;

FIG. 9 is a flowchart diagram of a subroutine
off FIG. 6;

FIG. 10 shows an example of images in the image
15 group S_0 after image processing;

FIG. 11 shows an example display of images in
the image group S_0 after changing a reference image;

FIG. 12 shows correction of image data to $\gamma=1$;

FIG. 13 is a lookup table after correction to
20 $\gamma=1$;

FIG. 14 is a lookup table with gamma
characteristics of display means; and

FIG. 15 is a block diagram of the apparatus.

25 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described in
detail based on embodiments shown in figures.

FIG. 1 is a block diagram of a photographing apparatus. Illuminating light emitted from a lamp 2 of a continuous light emission source emission-controlled by continuous illumination light source control means 3 and a stroboscopic tube 4 of a stroboscopic illuminating light source emission-controlled by stroboscopic light source control means 5 passes through a condenser lens 6, and is formed into a ring shape by a field lens 7 and a ring slit 8. The illuminating light formed into a ring shape passes through a relay lens 14 and detrimental light blocking members 9 and 15, is reflected by a perforated mirror 16, passes through an objective lens 17, and is applied to a subject eye E. A photographic portion is illuminated by the illuminating optical system. The continuous illuminating light source control means 3 and the stroboscopic light source control means 5 receives indications of the intensity of emitted light, light emission timing, light emission time and the like, and performs of predetermined light source control.

Light reflected from the subject eye E passes through again the objective lens 17, holes of the perforated mirror 16, a focus lens 18 movable along the optical axis, and an image formation optical system 23 to a flap mirror 24 installed in such a manner that it can be freely inserted into/removed

from a light path by a known drive means (not shown) operationally controlled by control means 35. If the flap mirror 24 is present in the light path, the light reflected from the subject eye E reaches a mirror 25, passes through a finder optical system 26, and forms an image on the pupil of eye e of the subject, so that the subject eye E to be examined can be visually observed.

If the flap mirror 24 is absent from the light path, the light reflected from the subject eye E reaches image pickup means 29 constituted by an electronic image pickup device 27 and image signal amplifying means 28, and forms an image on the electronic image pick up device 27, and an image signal output thereof is subjected to signal amplification processing in a predetermined gain (signal amplification factor) by the image signal amplifying means 28, sent to image process recording means 30 via known electric connection, and stored as an image. At the same time, it is sent to an image display apparatus 32 to provide display.

The image display apparatus 32 is under control by the control means 35, and is controlled for selection between display modes, and an input from the image pickup means 29 and an input from the image process recording means 30 are selectively displayed.

Furthermore, a transparent touch sensor 46 is

installed on the display screen of the image display apparatus 32, and if a position on the display screen is selected by a subject, the position information is inputted to the control means 35.

5 The image signal amplifying means 28 can select a gain by control from the control means 35. Furthermore, the light reception state of the electronic image pickup device 27 and the gain of the image signal amplifying means 28 can be monitored by
10 the control means 35 via the image signal amplifying means 28.

 Further, a spectral mirror 33 for taking part of photographing light is installed in a photographing light path, and a light intensity sensor 34 is
15 installed at the tip of the spectral light path. An output of the light intensity sensor 34 is inputted to the control means 35 and monitored as an indicator of a light exposure value of the electronic image pickup means 27. The control means 35 can
20 automatically control light source light intensity control functions of the continuous illuminating light source control means 3 and the stroboscopic light source control means 5 based on an input signal from the light intensity sensor 34 and the gain of
25 the image signal amplifying means 28.

 In the illuminating optical system, a visible fluorescent exciter filter 10 for visible fluorescent

contrast photography and an infrared fluorescent
exciter filter 12 for infrared fluorescent contrast
photography are installed in such a manner that they
can be inserted into/removed from the light path by
5 drive means 11 and 13 such as solenoids operationally
controlled by the control means 35, respectively.
Similarly, in an image pickup optical system, a
visible fluorescent barrier filter 19 for visible
fluorescent contrast photography and an infrared
10 fluorescent barrier filter 21 for infrared
fluorescent contrast photography are installed in
such a manner that they can be inserted into/removed
from the light path by drive means 20 and 22 such as
solenoids operationally controlled by control means
15 32, respectively. The exciter filter has the job of
extracting only exciting light for causing a
predetermined fluorescent contrast medium to generate
fluorescence from illuminating light. The barrier
filter has the job of blocking only exciting light of
20 fluorescent light and reflected exciting light from
the eye to be tested. These jobs are same for visible
light and infrared light.

In the case of a visible fluorescent
photographing mode, the control means 35 inserts at
25 least any one of the visible fluorescent exciter
filter 10 and the visible fluorescent barrier filter
19 into the light path.

In the case of an infrared fluorescent photographing mode, the control means 32 inserts at least any one of the infrared fluorescent exciter filter 12 and the infrared fluorescent barrier filter 21 into the light path.

In the case of a color photographing mode, none of the above filters is inserted into the light path. Selection between the photographing modes described above is performed by the control means 35 according to an input from mode selection inputting means 39.

As shown in FIG. 2, the control means 35 is comprised of main processing control means 50 performing control of operations of parts of the apparatus, control of operational modes, calculation processing, determination on a situation, and the like, calendar and clock means 51 ticking the date (year, month and day) and the time, a set value table 52 storing set values concerning apparatus control such as light intensity tables, gamma characteristics γ_c of the image pickup device 28 and gamma characteristics γ_c of the display means 32, an internal memory 53 temporarily storing external input values, set values read from a set value, results of calculation and the like, times of input of data and times of processing of data, and a peripheral device 54 supporting the main processing control means 50.

The main processing control means 50 establishes

electric connection with light intensity control means 35, image signal amplifying means 28, image recording means 30, image processing means 31, actuators 11, 13, 20, 22 and 24 and the like to perform predetermined control. Furthermore, the main processing control means 50 changes the contents of the parts upon reception of inputs from input means 37 to 44 and a touch panel 46, and inputs predetermined information to the image recording means 30 and the image processing means 31. Furthermore, it displays predetermined control information and input information on the display means 45.

FIG. 3 is an outline view of an ophthalmologic photographing apparatus in this embodiment. A photographing apparatus main body 60 is installed on a movable stage 61, and can freely move vertically, longitudinally and laterally within a structural movable range with respect to the subject eye Ea by manipulating a manipulation knob 36. Image pickup means 29 and a focus adjustment knob 63 are installed in the photographing apparatus main body 60. Image display means 32, the manipulation knob 36, a photographing switch 37 mounted thereon, a group of input means 38 to 44 and display means 45 are installed on the movable stage 61.

FIG. 4 shows the group of input means installed

on the movable stage 61. The photographing switch 37 is installed on the manipulation knob 36. When the photographing switch 37 is pressed (ON), the stroboscopic tube 4 emits light, and in
5 synchronization with the light emission, the electronic image pickup means 29 photographs an image of a predetermined site of the subject eye illuminated with stroboscopic light.

 A keyboard switch 38 for inputting characters
10 such as subject IDs and complicate settings for image processing and the like is provided on an operation panel, a plurality of subject IDs can be stored at a time in the control means 35, and the switch can be made between subject IDs by operating the keyboard
15 switch 38. Mode switching input means 39 for switching between photographing modes, a lamp adjustment dial 40 for setting the light intensity of the continuous illuminating light source 2, a stroboscopic adjustment dial 41 for setting the light
20 intensity of the stroboscopic illuminating light source 4, a gain dial 42 for setting a fixed gain of the image signal amplifying means 28, a timer switch 43 inputting to the control means 35 a signal marking a specific time at which the switch is pressed, a
25 filter switch 44 for inserting the exciter filters and the barrier filters into the light path and removing the same from the light path according to

the photographing mode, and display means 45
displaying the gains of the timer and the image
signal amplifying means 28, illuminating light
intensity, the photographing mode and the like are
5 installed.

FIG. 5 is a block circuitry diagram of the image
process recording means 30, in which control signals
and data are received by an input port 81, the data
is temporarily stored in temporary storage means 82
10 such as a solid memory, and the control signal is
inputted to a CPU 85. The CPU 85 controls the overall
image process recording means 30, processes data
stored in the temporary storage means 82 and
permanent storage means 31 such as a hard disk. From
15 an output port 84, data, the control signal and the
like processed by the CPU are outputted to outside.

When the subject eye is photographed with the
above configuration, processing and operations are
performed as described below. Before photographing
20 the subject eye, a photographing mode such as the
visible fluorescent contrast photographing mode or
infrared fluorescent contrast photographing mode is
set by the mode switching input means 39. A desired
gain G_n is set by the gain dial 42, the subject eye
25 E_a is aligned, and then a fluorescent contrast medium
is intravenously injected into the subject. In
synchronization with the intravenous injection, the

timer switch 43 is pressed to input a timer start time t_0 to the control means 35. The control means 35 continues to subtract the start time t_0 from a time T_n ticked by the calendar and clock means 51 to
5 calculate time t_n from the timer start. The time t_n is inputted to the image process recording means 30 for adding the time t_n to an image P_n photographed after the timer start.

A photographic site is observed with the finder
10 optical system 26 while the photographing switch 37 is pressed to photograph the site. At this time, the control means 35 compares the light exposure value monitor and the intensity of emitted light of the electronic image pickup means 27 by input from the
15 light intensity sensor 34 with the gain G_n of the image signal amplifying means 28 as described previously to make a setting automatically so that the intensity of emitted light becomes an appropriate light intensity F_n of the stroboscopic tube 4 via the
20 stroboscopic light source control means 5. A plurality of images P_n is photographed while changing the gain G_n as necessary. The photographing mode, the gain G_n and the light intensity F_n set as described above are temporarily stored in the internal memory
25 53 in the control means 35 while they are set.

At the time when the photographing of the image P_n is ended, the image P_n outputted from the

amplifying means 28 is captured in the temporary storage means 82 via the input port 81 of the image process recording means 30 shown in FIG. 5. At the same time, information of the photographing mode, gain G_n , light intensity F_n and timer time t_n stored in the internal memory 53 in the control means 35 is similarly captured in the temporary storage means 82 via the input port 81.

The CPU of the image process recording means 30 carries out processing for adding photographic condition parameters such as the photographing mode, the gain G_n , the light intensity F_n and the timer time t_n to the image P_n recorded in the temporary storage means 82, and records the image P_n in the permanent storage means 31 as one image of the image group S_o . n is any natural number, $n = 1 \rightarrow d \rightarrow m$.

At the time when the photographing of the subject in this photographing mode is ended, pressing the timer switch 43 again causes the control means 35 to stop the timer to end the capturing and recording of images belonging to the image group S_o in the image process recording means 30.

Details of image processing will be described below according to the flowchart shown in FIG, 6.

S001: When an image processing command is inputted to the image process recording means 30 from the control means 35, m images P_n in the image group

So recorded in the permanent storage means 31 and accompanying data of photographic conditions and the like are written in the temporary storage means 82. At the same time, the gamma γ_c of the image pickup means 27 is read in the temporary storage means 82 from the control means 35.

S002: The data read in the temporary storage means 82 is converted into images by the CPU 85 shown in FIG. 5, and some of them are displayed on the image display means 32 as shown in FIG. 7. The images displayed at this time have equal are displayed in equal brightness. In this example, the subject becomes darker with time, but may become brighter or cyclically brighter and then darker, and in any case, it can be considered that the same holds true.

S003: When the examiner designates an image to be selected as a reference image, the touch sensor 46 on the display screen of the image display apparatus 32 inputs a position on the display screen indicated by the examiner in the image process recording means 30 via the control means 35, and the image process recording means 30 recognizes an image displayed at this position and determines the image as a reference image Pd.

In the image process recording means 31, image processing is carried out as described below, whereby the image Pn can be expressed as an image

photographed under conditions of the light intensity F_d and gain G_d same as those for the image P_d .

S004: A function for comparing the light intensities F_d and F_n to convert the result into an
5 image correction value is determined to be $f_1 (F_d, F_n)$, and a function for comparing the gains G_d and G_n to convert the result into an image correction value is determined to be $f_2 (G_d, G_n)$.

In this embodiment, attention is given to the
10 intensity of received light at the light receiving surface of the image pickup device 27 at the time of photographing the image P_d for the image P_n , and the functions f_1 is defined as functions for determining the ratio of brightness of the images as follows.
15 Since the intensity of received light at the light receiving surface of the image pickup device 27 is proportional to the intensity of emitted light of the illuminating light source, the functions $f_1 (F_d, F_n)$ are expressed by following equation:

20
$$f_1 (F_d, F_n) = F_n/F_d \cdots (1)$$

For the function $f_2 (G_d, G_n)$, the gains G_d and G_n usually have a dB as a unit, and the amount of amplification E/E_o of the gain G_o is defined as follows:

25
$$E/E_o = 10^{(G_o/20)} \cdots (2)$$

Since the ratio of the intensity of received light at the light receiving surface of the image

pickup device 27 can be considered as the ratio of the amount of amplification, the function f2 is expressed by the following equation:

$$f2 (Gd, Gn) = \{10^{(Gn/20)}\} / \{10^{(Gd/20)}\} \cdots (4)$$

5 The image correction value Rn of the image Pn for the image Ph is expressed by the following equation:

$$Rn = f1 (Fn, Fd) \times f2 (Gn, Gd) = (Fn/Fd) \times \{10^{(Gn/20)}\} / \{10^{(Gd/20)}\} \cdots (5)$$

10 The lookup table of the image Pn has characteristics 70 of FIG. 8. The relation between the input V and the output p in the characteristics 70 is expressed by the following equation:

$$V = a \times (p^{\gamma c}) \because a = 1/p_{max} \cdots (6)$$

15 The right side in the equation is multiplied by the correction value Rn calculated by the equation (5) to obtain the following equation:

$$V = Rn \times a \times (p^{\gamma c}) \cdots (7)$$

20 Using the light intensity Fd and gain Gd of the image Pd and the light intensity Fn and gain Gn of the image Pn read in the memory 82, and γ of the image pickup mean, the CPU 85 of the image process recording means 30 shown in FIG. 5 calculates the correction value Rn using the equation (5) for the m
25 images Pn in the image group So, successively creates a lookup table Ln shown in characteristics 71 ($Rn > 1$) or characteristics 72 ($Rn < 1$) determined by the

equation (7) as shown in the flowchart of FIG. 9, and stores the same in the memory 87.

In the flowchart of FIG. 9, the following steps are carried out.

5 S101: First, an initial value $n=0$ is assigned to n .

 S102: R_n is determined according to the equation (5).

 S103: V is determined according to the equation
10 (7).

 S104: The lookup table L_n is determined and stored in the memory 87.

 S105: Next calculation is performed with $n = n+1$.

 S106: The above operations are repeated until n
15 $= m$.

By the above operations, the lookup table L_n is created.

 S005: The lookup table L_n created based on the flowchart of FIG. 9 is used for display of the image
20 P_n to express the image as an image photographed under the intensity F_d of emitted light when the image P_d is photographed and the gain G_d during photographing.

 FIG. 10 shows display in the image display means
25 32 after processing all images in the image group S_o after being subjected to the above image processing. Images are expressed with different brightness levels

with respect to the reference image Ph.

S006: If an image Pd' other than the image Pd is selected in this state in the same manner as described previously, the reference image is changed
5 from the image Ph to the image Pd', the image processing described previously is newly carried out with the image Pd' as a reference, and display is provided in the image display means 32 as shown in FIG. 11.

10 Furthermore, for satisfactorily displaying the image distant from the reference image Pd, the right side of the equation (7) is multiplied by a compression factor b ($b < 1$) to obtain the following equation.

15
$$V = b \times R_n \times a \times (p^{\gamma_c}) \cdots (8)$$

A lookup table Ln' shown in characteristics 73 ($R_n > 1$) or characteristics 74 ($R_n < 1$) determined by the equation (8) may be created and used for expression of the image Pn other than the reference image Pd.

20 In this case, the image is expressed with a difference in brightness of the actual subject compressed, and therefore the shade should be carefully read.

For improving the accuracy of reproduction, the
25 lookup table of the image Pn is subjected to processing for canceling the characteristics of the image pickup means 27, and then a lookup table Ln for

display with the result of the processing corrected with the correction value R_n is created.

Image data of the image P_n shown in the lookup table characteristics 70 of FIG. 12 is powered by an
5 inverse of gamma characteristics γ_c of the image pickup means 27 to correct $\gamma = 1$ shown in the characteristics 75 for the image data.

As shown in FIG. 13, the lookup table of the image P_n has characteristics 75. The relation between
10 the input V and the output p in the characteristics 75 is expressed by the following equation:

$$V = p \cdots (9)$$

The right side of the equation (9) is multiplied by the correction value R_n calculated by the equation
15 (5) to obtain the following correction equation.

$$V = R_n \times p \cdots (10)$$

For the image P_n in the image group S_o , a lookup table L_n shown in the characteristics 76 ($R_n > 1$) or
characteristics 77 ($R_n < 1$) determined by the equation
20 (10) is created and used for display of the image P_n .

Further, for improving the accuracy in terms of display, the lookup table is corrected with γ
characteristics γ_m of the display means 32 adapted to the characteristics 76 ($R_n > 1$) or characteristics 77
25 ($R_n < 1$).

For the characteristics 76 ($R_n > 1$) or characteristics 77 ($R_n < 1$) shown in the equation (10)

of FIG. 14, p of the right side of the equation (10) is powered by γ characteristics γ_m of the display means 32 to obtain the following correction equation.

$$V = R_n \times p^{\gamma_m} \dots (11)$$

5 For the image P_n in the image group S_o , a lookup table L_n'' shown in characteristics 78 ($R_n > 1$) or characteristics 79 ($R_n < 1$) determined by the equation (11) is created and used for display of the image P_n .

 In the above image correction, both the
10 intensity of emitted light and gain are used as parameters, but it is also possible to fix one of the parameters to determine a correction amount with one parameter. In this case, 1 may be assigned to f_1 (F_n , F_d) or f_2 (G_n , G_d) as necessary.

15 Other than selecting an image with the touch sensor, an image may be selected with a cursor key or the like provided in the keyboard switch 38, or an image ID may be entered through the keyboard switch 38 to select an image.

20 As shown in FIG. 15, a liquid crystal board or a transmittance variable member 47 capable of changing the transmittances of a plurality of selectable ND filters or the like having different transmittances is placed in front of the electronic image pickup
25 means 27, and the member 47 is situated under control by the control means 35. If the transmittance variable member 47 is changed so that the light-

exposure value of the electronic image pickup means 29 is an appropriate value, according to the light intensity in the illuminating light system detected from the output of the light intensity sensor 34 by the control means 35, and the electronic image pickup means 27 is configured so that its light exposure value can be adjusted, the member 47 can be used as an alternative or aid for change of the intensity of emitted light of the stroboscopic tube 4 and change of the gain of the image signal amplifying means 28. In other words, the transmittance can be used as a photographic condition parameter.

The transmittances of the transmittance variable member 47 during photographing of the reference image P_d and any image P_n are determined to be E_d and E_n , respectively, and as a function for determining a brightness ratio at the light receiving surface of the image pickup element 27 during photographing of the image P_d for the image P_n as described previously, f_3 is defined as follows.

If ND is employed as a unit of the transmittance, the intensity of transmitted light when $ND = E_n$ holds equals $1/(10^{E_n}) \times 100$ (%), and thus the function f_3 is expressed by the following equation:

$$f_3(E_n, E_d) = (10^{E_n}) / (10^{E_d}) \cdots (8).$$

If the equation (5) is multiplied by this function, the transmittance can be used as a photographic

condition parameter.

In the above example, additional information such as the image ID parameter and the photographic condition parameter is added to the image itself and
5 recorded in the image process recording means 30 but, for example, each of the image and additional information of the image can be given the same serial number and separately recorded, called as necessary utilizing the added serial number, and used as
10 integral image information.

The control means 35 can serve also as the CPU 85 of the image process storing means 30.

Furthermore, instead of including the image process storing means 30 and the image display means
15 32 in the ophthalmologic photographing apparatus, they may be independently provided as the processing apparatus and the display apparatus and electrically connected to the control means 35 of the ophthalmologic photographing apparatus main body to
20 form one ophthalmologic photographing apparatus as a whole as a matter of course.

As described above, in the ophthalmologic apparatus according to the present invention, an image in an optimum exposure state can be obtained by
25 correction of the light exposure value and adjustment of the amplification factor of an image signal using electronic image pickup means having a small latitude

(exposure allowable range) even in the photographing
of a subject of which the brightness of a
photographing object largely changes as in
fluorescent contrast photography, while a change in
5 brightness of a fluorescent contrast image with time
due to loss of brightness by correction of the light
exposure value and adjustment of the amplification
factor of the image signal can be visually determined.
That is, storage of images, retrieval and convenience
10 of application associated with electronic image
photography are added to the diagnostic value of the
image obtained with the conventional silver
photographed image, resulting in a significant
improvement in value of the photographed image.

15